Multi-Objective Design Optimization of 100 kW Non-Rare-Earth or Reduced-Rare-Earth Machines

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Project ID: elt248

Timeline and Budget

- Project Start: May 2019
- Project End: May 2024
- Percent Complete: 60%
- \$1.5M over 5 years; \$300k/year

Barriers and Targets

Electrical and Electronics Technical Team Roadmap October 2017

- Non-rare-earth machines as insurance policy against rare-earth magnet price volatility
- Improved materials (i.e. copper, steel) to cut costs in half and double reliability
- Understanding of system-level trade-offs (i.e. cost/performance impact of material substitution
- 50 kW/l; 5 kW/kg; \$3.3/kW
- 100 kW machine at 0.2 sqrt(m^3 kg)

Partners

- Oak Ridge National Laboratory
- Sandia National Laboratories
- University of Wisconsin
- Illinois Institute of Technology
- NC State University

Relevance

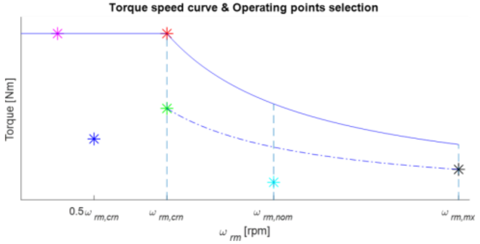
Focus on achieving DOE performance objectives using under considered heavy-rare earth free machines.

Milestones

Milestone	Completed
DHAM-PMAC comparison (T)	6/32/21
ICM code complete (T)	9/30/21
ARM code complete (T)	12/30/21
Comprehensive evaluation (G/N)	3/31/22

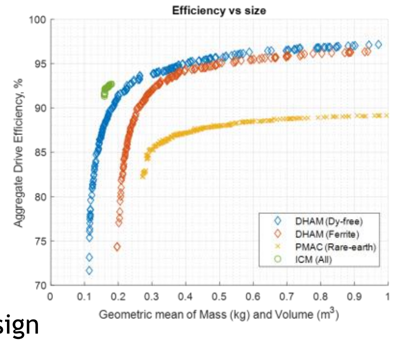
Approach

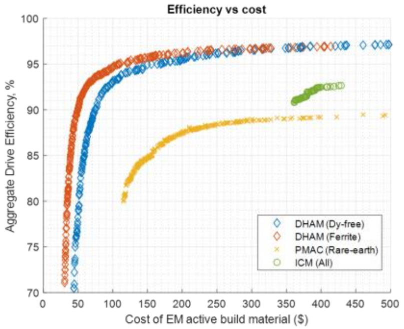
- Compare machine classes for common specifications in terms of multi-objective design optimization
- Machines considered:
  - Permanent magnet ac (PMAC)
  - Asymmetrical reluctance machine (ARM)
  - Dual rotor homopolar ac machine (DHAM)
  - Inert core machine (ICM)
- Common specifications:



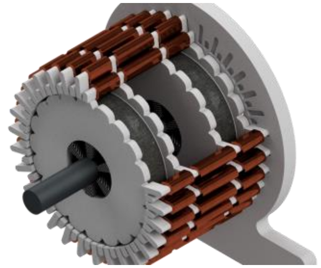
Rating	Value
α_{CPSR}	3
$P_{mx,pk}$ (kW)	100
$P_{mx,ct}$ (kW)	55
$P_{nom,ct}$ (kW)	27.5
$\omega_{rm,mx}$ (rpm)	20,000
$\omega_{rm,crn}$ (rpm)	$\omega_{rm,mx}/\alpha_{CPSR}$
$\omega_{rm,nom}$ (rpm)	$\sqrt{\omega_{rm,crn}\omega_{rm,mx}}$

Technical Accomplishments/Progress



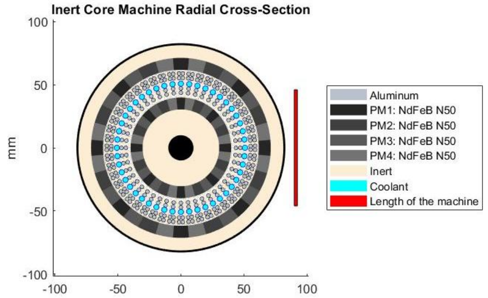


DHAM Sample Design



Magnet type: NdFeB N52DF
Stator steel: M15
Rotor steel: M15
EM active mass: 9.55 kg
EM material price : \$95.30

ICM Sample Design



Magnet type: NdFeB N50
Stator: Duraform
Rotor: Duraform
EM active mass: 6.25 kg
EM material price :\$385

Remaining Challenges/Barriers

Vary by machine

- ARM: Non-competitive
- ICM: Need to reduce cost
- DHAM: Looks viable
  - This machine does not yet exist
  - Need to develop control system
  - Need improved magnetic design model
  - Need a prototype!

Planned Future Work

Year 4 (SOPO)

- Final design code revision
- Final design validation (FEA)
- Detailed design
- Machine pre-build

ICM Development

- Constructing machines with plastic cores
- Hardware validation of slot cooling
- Converter topology for low inductance

DHAM Prototype

- 10 kW, 3600 rpm scale
- Build will start Summer 2022
- Control algorithm
- Time-domain simulation

DHAM Aircraft Applications (New Funding)

Summary

The DHAM is a viable and valuable technology for producing power dense, dysprosium free electric machines for vehicle applications. ICM is power dense, has nearly zero torque ripple, no magnet loss